Renewable and Sustainable Energy Reviews 21 (2013) 603–613

Contents lists available at SciVerse ScienceDirect

Renewable and Sustainable Energy Reviews

journal homepage: www.elsevier.com/locate/rser

Focus on the development of shale gas in China—Based on SWOT analysis

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ARTICLE INFO

Article history:
Received 12 September 2012
Received in revised form
21 December 2012
Accepted 26 December 2012
Available online 13 February 2013

Keywords:
China
Shale gas industry
SWOT analysis

ABSTRACT

As an unconventional natural gas with the advantages of great resource potential and low carbon emissions, shale gas has currently aroused a new round of development and utilization worldwide. China's shale gas resource is enormous and has huge potential for exploitation. However, due to the late start of exploration and development, it has not yet realized industrialization. By using the SWOT analysis method, this paper studies the internal and external development environment of Chinese shale gas, then explores shale gas development status of China from four dimensions including strengths, weaknesses, opportunities and threats. Finally, according to the combinations of SWOT matrix analysis, the paper formulates four kinds of different development strategies to provide certain references to the development of China's shale gas industry.

Contents

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http://dx.doi.org/10.1016/j.rser.2012.12.044

1. Introduction

With the increase of energy consumption, conventional natural gas resources are gradually reducing and getting increasingly difficult to develop. Due to its large amount of reserves and the advantage of low carbon emissions, unconventional gas resources which include shale gas have attracted more and more attentions. The United States is the earliest and the most successful country in developing and utilizing shale gas. Data of the U.S. Energy Information Administration (EIA) shows that the U.S. shale gas industry has achieved rapid growth since 2000. In 2010 the output has reached $1378 \times 10^8\,m^3$, with an average annual growth rate of 47.7% [1]. The great success from the development of shale gas not only reversed the situation of America as a gas importing country but also brought profound influence to the international gas market as well as the world energy framework. As a result, a new rush of shale gas development is booming globally.

Because of the abundant resources and the huge potential for exploitation, China is now strengthening the development and utilization of shale gas resources. The development of shale gas will become the strategic choice of China to realize the secure and diversified energy supply [2], and it is also an effective way for China to transform into the clean energy economy mode. The 12th Five-Year Plan for National Economic and Social Development of the People's Republic of China explicitly requests to "promote the development and utilization of shale gas and other unconventional oil and gas resources". Upon this, in March 2012, the National Energy Bureau (NEB), Ministry of Land and Resources (MLR) jointly compiled and issued the 12th Five-Year Development Plan for Shale Gas (2011–2015) [3](short for the Plan (2011–2015)). The Plan (2011–2015) pointed out that the development of shale gas would have great significance in promoting scientific and technological progress, economic growth, improving energy structure and safeguarding energy security, protecting ecological environment. As the promulgation of the Plan (2011–2015), China's shale gas development and utilization entered into a new stage.

Many scholars are dedicated to studying the shale gas as the government is vigorously promoting the development of the shale gas industry. In the field of predicting the potential of development of shale gas industry, Yanping and Meng [4] develops the comprehensive evaluation model of the development prospects of the shale gas from the perspective of fuzzy mathematics. Li et al. [5] and others advised to comprehensively use analogy and volumetric method to estimate the amount of resources. Fujie et al. [6] predicted the shale gas resources in China and pointed out the existing problems of the field of theoretical research. Denghong et al. [7] introduced dynamic analysis methods on shale gas production capacity. In the technical field, Xin et al. [8] compared and evaluated the key parameters of coalbed gas, conventional natural gas and shale gas reservoirs, focused on analyzing horizontal drilling and hydraulic fracturing technology which promoting the development of shale gas. Based on the current status of world shale gas development, Dengke et al. [9] analyzed major foreign development techniques from different perspectives. In the aspects of systems and policies, Gang [10] made their points that China needs to use American experience for reference reasonably. Jian et al. [11] summarized the United States policy and development models, proposed countermeasures and suggestions on supporting the establishment of policies and accelerating technological innovation. Through the in-depth study of the North American shale gas reservoirs, Yong and Haibo [12] pointed out that the effective exploration and development lies in the application of policy guidance and technology. As for the current problems in the research and development of shale gas, Guangming et al. [13] pointed out the problems of China to accelerate the development of shale gas and to realize industrialization. Jiping [14] reviewed the process of the development of China's shale gas, pointed out the outstanding issues of the development of China's shale gas industry and made recommendations.

The Chinese government strongly supports the development and utilization of shale gas. On the one hand, it has actively formulated various preferential and supportive policies to guide and support shale gas industry development; on the other hand, it is committed to encourage and promote international cooperation. It is reported that communications and cooperation either in government or firm level which provide opportunities for China's shale gas industry development have been carried out between China and the United States. Based on the detailed discourse of the status quo of China's shale gas, this paper uses SWOT analysis method to comprehensively analyze the internal strengths and weaknesses and external opportunities and threats. Next, the SWOT matrix was constructed on this basis. In line with the principle of exerting strengths, overcoming weaknesses, exploiting opportunities and defusing the threats, this paper combines all the factors already taken into account, finally draws a series of alternative strategies and responses of development of this industry in the near future. Finally, it provides references for the formulation of the supportive policies for the development of the shale gas industry.

2. The status quo of China's shale gas industry development

2.1. Resource situation

In 2011, in order to gradually solve the problem of finding out the resource potential and regional distribution, the MLR conducted a survey on preliminary evaluation of the Mainland's shale gas resource potential and initially established preferred favorable and prospective areas. It also divides shale gas reservoir target areas into five regions indicated in Fig. 1, they are South China (along the Yangtze: Sichuan, Chongqing, Hunan, Hubei, Yunnan, Guizhou and Guangxi vicinity, etc.), North China, Northeast China (Songliao Plain), Northwest China (including Turpan–Hami Basin and Ordos Basin) and the Qinghai–Tibet. According to the survey [4], the nation's shale gas geological resource potential shown in Table 1 is up to 134.42 trillion cubic meters (excluding Qinghai and Tibetan). The gas resources mainly distribute in Upper Yangtze and Dian-Qian-Gui (i.e., Yunnan and Guizhou Province) Areas, North and Northeast China, Mid-lower Yangtze and Southeast China, Northwest China.

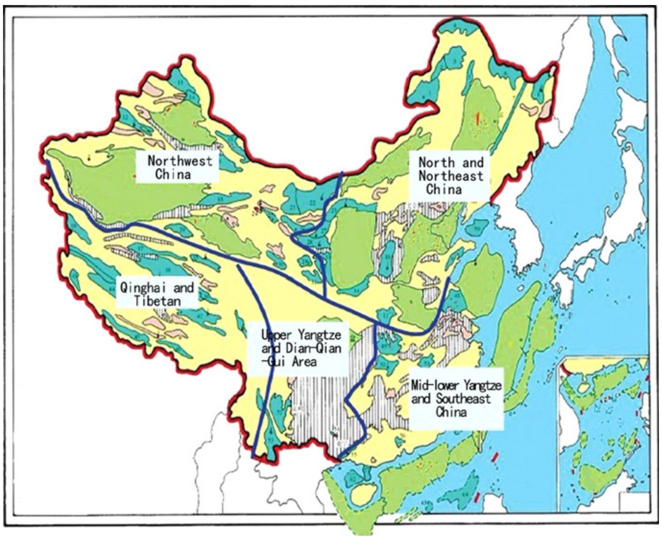


Fig. 1. China's shale gas distribution pattern.

Table 1
Areal distribution of China's shale gas resource potential

Area	Resource potential (Trillions of cubic meters)	Percentage (%)
Upper Yangtze and Dian-Qian-Gui Area	62.56	46
North and Northeast China	26.79	20
Mid-lower Yangtze and Southeast China	25.16	19
Northwest China	19.90	15

Table 2
Geographical distribution of China's mineable shale gas resource potential

Area	Resource potential (Trillions of cubic meters)	Proportion (%)
Upper Yangtze and Dian-Qian-Gui Area	9.94	39.63
North and Northeast China	6.70	26.70
Mid-lower Yangtze and Southeast China	4.64	18.49
Northwest China	3.81	15.19

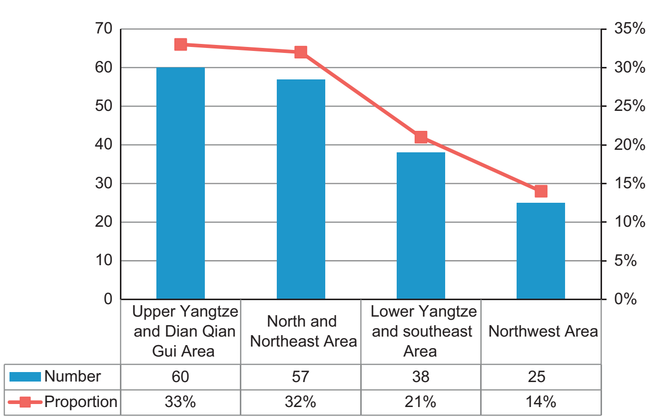


Fig. 2. China's shale gas preferably favorable areas and theirs distribution.

The results of the survey showed that China's mineable resource potential amounts to 25.08 trillion cubic meters (excluding Qinghai and Tibetan areas). Table 2 displays the main distribution areas and its resource potential. In addition, in the National Oil and Gas Resources Strategic Area Selection Project, the MLR set the Survey of National Shale Gas Resource Potential Evaluation and Favorable Areas Preferentially Selected Project. The evaluation results of the project have selected out 180 shale gas favorable areas, Fig. 2 illustrates their distribution.

2.2. Development status

At present, China's shale gas development is still in the initial stage and the investment scale is small. But all the signs show that some prime domestic petroleum enterprises such as China National Petroleum Corporation (CNPC), Sinopec Group, China National Offshore Oil Corporation (CNOOC) etc., are strengthening shale gas exploration and development step by step. In recent years, the petroleum enterprises' shale gas explorations mainly concentrated on Sichuan Basin and its periphery, Ordos Basin, Eastern Depression of Liaohe River and other regions. By the end of 2011, China's petroleum enterprises have nearly drilled 30 shale gas exploratory wells, in which 18 wells obtained industrial gas flow by fracturing. Among the companies, CNCP and Sinopec Group, respectively, drilled and fractured their first shale gas horizontal well.

Table 3 reveals China's shale gas exploration progresses. Among the progresses, China's shale gas explorations are mainly focused on Sichuan Basin and its periphery, Ordos Basin, main basins in Northwest area. Through all these years of painstaking efforts, China has made some achievements, they are displayed in Table 4.

Global shale gas development is now drawing a lot of attentions, however, countries with rich reservoir of shale gas are in different phases of development. The U.S. whose shale gas has been developed over 80 years is currently the only one country to achieve shale gas commercialization and industrialization, the United States has entered a period of rapid development of shale gas. Canada's commercial exploitation is still in its infancy while exploration work of China and the Europe has only just begun in recent years. According to the above analysis of shale gas resource situation and development status, it is easy to draw a comparison between China and the United States, Canada, and Europe, and the specific results of this comparison are demonstrated in Table 5. By comparison, it can clearly show its own strengths and weaknesses of the development of shale gas in China, as well as the opportunities and threats from the outside. China faces not only opportunities but also challenges, it has to bring the strengths into full play and overcome its own weaknesses.

3. SWOT analysis method

SWOT analysis method is an analysis method concerning competitive situation, largely used for strategic analysis process. In other words, it is an effective strategy development tool. It was first proposed by Weihrich, a professor of management in the University of San Francisco. He proposed the method when he was studying the competitiveness and strategies of enterprises in the early 1980s. "SWOT" is the abbreviation for the capital word of Strength, Weakness, Opportunities and Threat, in which "S" and "W" are internal factors while "O" and "T" are external factors [38]. It is commonly accepted that an industry's strengths and weaknesses demonstrate the industry's internal characteristics and are controllable; and an industry's opportunities and threats are determined by external factors on which the industry has no direct control but can react to its own advantage. SWOT analysis is a methodology allowing an industry to understand and plan to use their strengths to exploit opportunities, to recognize

Table 3
Advances in shale gas exploration work.

Date	Exploration party	Activities	Significance
2009.10	Ministry of Land and Resources	Started the Project of Shale Gas Resource Exploration in Qijiang County, Chongqing City	China's first shale gas resource exploration project
2009	China National Petroleum Corporation	Registered the ore rights in North Yunnan and Guizhou area, started to excavate Sichuan Basin's shale gas data well	Opened the prelude of pre-exploration of shale gas
2010.8	Langfang Branch Institute of the Research Institute of Petroleum Exploration and Development	Established the Shale Gas R&D Center of National Energy	China's first scientific research institution specialized in shale gas development
2010.9	China National Petroleum Corporation	Developed the southwest oil and gas field's Wei 201 well	Got wellhead-tested daily capacity of 10,800 m^3 industrial gas flow
2010	NO.4 Factory of Jianghan Oilfield of Sinopec Group	Manufacturing type 2500 fracturing truck, completed the operation of the first well which is in the fracturing phase	Marks the shale gas exploration and exploitation in China has made substantial progress[5]
2011.3	CNPC Chuanqing Drilling Engineering Company	Drilled the first domestic shale gas horizontal well – Wei 201 – H1 well	Successfully put the oil-string casing to the goal layer, well complete the well
2011.5	Shanxi Yanchang Petroleum Group	Explored China's domestic first continental shale gas well–Liuping 177 well	Marked Shanxi Yanchang Petroleum has made substantial progress and significant breakthrough in unconventional oil and gas resources development

Table 4
Concentration zones and exploration results of China's shale gas exploration.

Exploration party	Region	Results
China National Petroleum Corporation	South Sichuan Province and North Yunnan Province	Preferentially selected four favorable blocks (i.e., Weiyuan, Changning, Zhaotong and Fushun-Yongchuan), drilled 11 appraisal wells, among them 4 vertical wells obtained industrial gas flow
Sinopec Group	East Guizhou Province, South Anhui Province, Northeast Sichuan Province	Drilled five appraisal wells, of which 2 wells obtained industrial gas flow; preferentially selected favorable blocks such as Jiannan and Huangping
Yanchang Petroleum Group	Yanan, Shanxi	3 wells found continental shale gas
China Coalbed Methane (CBM)	Qinshui Basin of Shanxi Province	Preferentially selected three favorable blocks (i.e., Shouyang, Qinyuan and Jincheng)

Table 5
Comparisons of the situation of shale gas development in some countries.

Content	China	The U.S.	Canada	Europe
Resource potential (Reserves)	134.42 trillion cubic meters (excluding Qinghai and Tibetan)	141.6–169.9 trillion cubic meters	15.57–24.35 trillion cubic meters (Only the western region)	Nearly half of the 350 billion cubic meters unconventional gas is shale gas
Mineable resource potential	25.08 trillion cubic meters (excluding Qinghai and Tibetan areas)	24.41 trillion cubic meters	Unknown	Unknown
History of the development	Since 2009	More than 80 years	Few decades, only behind the United States	Germany drilled the first exploration wells in 2008
Government attitude	Strongly supports	Strongly supports	Strongly supports	Support is not enough
Industry status	Testing and drilling wells	Large-scale production, commercial utilization	Bulk drilling and large commercial exploitation has just started	Exploration in infancy
Number of shale gas wells	Nearly 30 (until the end of 2011)	40 thousand	Unknown	Unknown
Market conditions	Transition from monopoly to competition	Full of small private companies with competition	In the introduction period of market competition mechanism	Not yet formed competitive situation
Investment status	More and more investment entities enter into the market	Investment diversification	Dozens of investment companies (including foreign)	At least 40 companies looking for shale gas
Density of the pipe network	100 thousand kilometers	Two million kilometers	Inter-regional imbalance, some provinces have developed intercontinental pipeline	More than 15.6 thousand kilometers of trunk line and 119.5 thousand kilometers of gas distribution pipelines

and repair or avoid their weaknesses, and to defend against or sidestep any threats. The method has been widely used as a strategic planning tool and found it was effective.

In this paper, S, W, O and T factors involved in the shale gas industry in China are proposed and analyzed with qualitative methods in the next part. We rank these factors according to their influences on the development of China's shale gas and put the factors that are significant as well as direct prior while the factors that are indirect later. Data used in the analysis stem from multiple sources including literature review, statistical reports,

government regulations and policies. These findings should provide a valuable reference to assess and evaluate the shale gas industry in China.

4. SWOT analysis of shale gas industrial development in China

China's shale gas resource potential is tremendous. However, at present, shale gas resource surveys and explorations are still in their initial stage. Chinese government attaches great importance to shale gas development, and encourages domestic enterprises to innovate independently while cooperate with foreign countries and enterprises which are developed in the field of shale gas. There are good opportunities and beneficial environment for Chinese native and foreign enterprises to cooperatively develop shale gas in China. As an unconventional natural gas which is promising to change China's gas exploitation pattern, shale gas will confront unprecedented opportunities for development during the 12th Five-Year-Plan period. However, Chinese shale gas development is still faced with many challenges and threats at the same time. The following part using the SWOT analysis method this paper analyzes the internal and external environment for the development of China's shale gas from four dimensions to study the internal strengths, weaknesses and external opportunities, threats. It ranks the various factors included in the strengths, weaknesses, opportunities, and threats according to their priorities or impacts, puts the direct as well as significant factors in the first while the indirect and short-term factors later.

4.1. Strengths

4.1.1. Abundant resource reserves

According to the relevant data issued by MLR, the nation's shale gas geological resource potential is up to 134.42 trillion cubic meters (excluding Qinghai and Tibetan areas) and the national mineable shale gas reserves reaches 25.08 trillion cubic meters (excluding Qinghai and Tibetan areas), they are widely distributed in Upper Yangtze and Dian-Qian-Gui Areas, North and Northeast China, Mid-lower Yangtze and Southeast China, Northwest China. This means that, once the shale gas is put into industrial production, the proportion of clean energy in China's total energy consumption will be greatly increased. This figure also makes China exceed America's reserves—currently the largest producer of shale gas in the world. EIA in World Shale Gas Resources: An Initial Assessment of 14 Regions outside the United States [6] revealed that the United States had only 24.41 trillion cubic meters for exploitation. The evaluation units of China which have got industrial gas or shale gas are about 880,000 square kilometers, geological resources are 93.01 trillion cubic meters, the mineable resource are 15.95 trillion cubic meters. In addition, the MLR selected 180 favorable blocks for shale gas. From the data above we can see that Chinese shale gas resources are abundant and widely distributed, and have tremendous potential for development.

4.1.2. 2Great development potential

The Shale Gas Development Plan (2011–2015) clearly defined the development goals of future development and utilization, namely, by the end of the 12th Five-Year-Plan period the proven mineable reserves of shale gas will be up to 2000×10^8 m^3, with 65×10^8 m^3 of annual output. Meanwhile, the Plan has raised some strategic planning for the industrialization of shale gas during the 13th Five-Year-Plan period. First of all, the government should further increase investment and greatly improve the production scale of the 19 exploration and exploitation zones provided that the resource situation is clarified and exploration and development technology breakthrough. At the same time, it encourages to vigorously promote the exploration and development of Dongting–Poyang Lake, Jiangsu–Zhejiang–Anhui, Ordos, South North China, Songliao Plain, Junggar Basin, Tuha Basin, Tarim Basin, Bohai Bay, and build the new shale gas exploitation zones to strive for the annual output to reach 600–1000 billion cubic meters by 2020. In 2015, Chinese shale gas output should reach 65×10^8 m^3 per year, this is the first announced target for shale gas production. Hence, China's shale gas will have incomparably broad market that other resources cannot catch up with.

4.1.3. High environmental benefits

Symbolized by Copenhagen Climate Change Conference, development of low carbon economy has become the consensus of the international community. As a clean and efficient fossil energy, natural gas is not only the bridge to transfer to the renewable energy but also the important pillar of low carbon economy. With its abundant reserves, shale gas brought hope to solve the shortage of natural gas. According to the calculation, 1 trillion cubic meters of shale gas can provide the energy equivalent to 1.33 billion tons of standard coal can provide [7]. In other words, to get the same calories, the use of shale gas can achieve 40% emission reduction. Such huge environmental benefits make shale gas a great attraction.

4.1.4. Long lifetime for exploitation

China's widely distributed shale rocks are thick and generally contain a large amount of gas, these make shale gas wells can produce gas with a stable rate for a longer time. Take South Yangtze River areas as an example, from Sinian to Triassic, marine deposits continuously developed in a wide range, the distribution areas are more than 200×10^4 square kilometers; the thickness of black shale layers is up to 10 km [8]. As a result of favorable development conditions, rich organic matters and high maturity, slow production decline rate, Chinese shale gas can produce stably for a longer time which is advantageous to shale gas industry development.

4.2. Weaknesses

4.2.1. Lack of funds

Data shows that shale gas resources of main basins and regions are about 15 trillion–30 trillion cubic meters, basically equivalent to the 28.3 trillion cubic meters of the United States [9]. Though China has a huge amount of shale gas reserves, many of them are kept deep in the geological structure that is hard to extract, for example, the seriously fractured Sichuan Basin. At the same time, China also lacks infrastructures including broad pipeline network and professional workers that will make the exploitation achievable and successful. Related equipment and facilities, technologies and qualified personnel, all these require large investment funds. According to relevant data[1], per meter costs of vertical and horizontal well of shale gas in China are $20,000 and $30,000, respectively. Digging a well that is 3000 m in depth, at least needs more than 300 million RMB ($0.047612 billion). According to Zhang Dawei [9], the Deputy Director of Oil and Gas Resource Strategic Research Center of MLR, to make the plan realized in 2020, China needs to dig 20,000 wells, calculated by 10 years, then the next 10 years China needs at least invest 600 billion RMB ($95.238095 billion), this will lead to the whole industry faces financial deficit.

[1] 〈http://money.163.com/12/0704/05/85HV8SDF00253B0H.html〉

4.2.2. Lack of key technologies

Lacking key technologies is another obstacle that restricts shale gas industrialization in China. On the one hand, China's shale gas is still in the infant stage of development, key technologies especially the horizontal well and sectional fracturing technologies are still in research. This seriously constrains the exploration and development, and even affects the grasp of the prospect of shale gas, finally badly influences the confidence of development of shale gas. On the other hand, China's geological conditions are more complex than the countries like the U.S. who is devoted to developing shale gas. In China, shale gas storage has unique geological characteristic, later reconstruction needs intense workloads because of the poor preservation conditions, shale gas formation and enrichment mechanism are more complex. Therefore, China will face more severe challenges from technologies and cannot simply adopt foreign technologies and equipments.

4.2.3. Prominent water treatment problems

At present, shale gas exploitation mainly uses hydraulic fracturing which needs a lot of water. Take Barnett Shale as an example, the average water consumption for drilling a well is 182 t while fracturing a well is 13,650 t [10]. As a result, one of the key points of developing shale gas successfully is to ensure that water supplied to drilling and fracturing wells should not conflict with residential and agricultural usage. Although the international leading countries of shale gas development are trying to reduce the water consumption, maintaining enough water supply is still an inevitable obstacle for China. What's more, waste water treatment is also a big problem. It needs to develop both environmental-friendly and economic scheme to solve water related problems. If there is no sewage treatment equipment near the well site, it will greatly slow down the speed of shale gas development and increase the cost of development. For countries such like China whose water resources is not rich, choose the areas with relatively rich water for test and actively develop recycling technology will be the key to the bright future of shale gas in China.

4.2.4. Serious environmental risks

Though shale gas is a kind of clean energy, it will cause more serious environmental risks in production process than conventional oil and gas. On the one hand, in the process of mining, the application of hydraulic fracturing needs to use chemicals which may possibly pollute underground water or cause chemical leakage to harm the environment, especially the groundwater system. On the other hand, the process of exploiting wills leads to the leakage of methane, a kind of greenhouse gas whose pollution effect is several times stronger than carbon dioxide. In addition, the impact caused by the earth surface is large in the process of exploration and development. Shale gas favorable areas in southern China almost locate in hilly and remote areas such as Changning and Weiyuan where cultivated land is fertile but small with large population, the traffic and water supply is limited. Consequently, not only well site selection is limited, but also shale gas production is easy affected by environment factors. Allows for these factors, the shale gas mining activities are confronted with a lot of environmental uncertainties.

4.3. Opportunities

4.3.1. Huge potential market

With China's rapid economic development, the demand for energy is continuously growing. Fig. 3 illuminates that the gap between supply and demand of natural gas is getting wider and

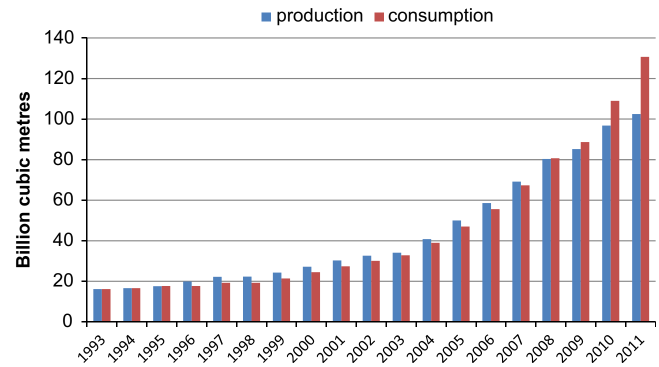


Fig. 3. Natural gas production and consumption in China. *Data Resource*: the BP Statistical Review of World Energy 2011.

wider. China's natural gas production in 2011 was $102.5\times10^9\,m^3$, while consumption is $130.7\times10^9\,m^3$. The gap between supply and demand is almost $28.2\times10^9\,m^3$ [11]. According to the National Energy Development Plan, natural gas in total energy consumption will increase from 4.9% in 2010 to 10% in 20,120, and the demand for natural gas will reach $3200\times10^8\,m^3$ to $3700\times10^8\,m^3$. However, the production of conventional natural gas is only $1600\times10^8\,m^3$ to $1800\times10^8\,m^3$. The gap is nearly half [12]. To ensure that the country's consumer demand for natural gas, except the imports of a certain amount of natural gas, China must rely on the development of shale gas. According to prediction of the Ministry of Land and Resources, by 2020, China's shale gas production will reach 8% to 12% of conventional natural gas; by 2035, shale gas production will reach $1100\times10^8\,m^3$ and account for 25% of the total production of natural gas. Shale gas will become a kind of important clean energy resource for China. Therefore, the 12th five-year plan period will be undoubtedly an opportunity for the rapid development of the shale gas industry in China.

4.3.2. Policy support

Scientific Development of 2030 National Energy Strategy which is being formulated puts shale gas in an important position. The 12th Five-Year Plan for National Economic and Social Development of the People's Republic of China clearly stated that "to promote the development and utilization of unconventional oil and gas resource such as shale gas." In order to encourage multiple capitals to enter into the shale gas exploitation and promote the development of China's shale gas industry, the government has made a series of corresponding development plans. The Shale Gas Development Plan (2011–2015) has already been issued in March 2012. This is China's first shale gas development planning as well as the most important guidance for shale gas exploration and development during 2011–2015. It objectively analyzes Chinese shale gas resource potential and current situation of exploration. It also points out the problems that China faces, and ascertains the guiding ideology, target, main tasks and planning measures. Finally, it determines the blueprint of developing shale gas during the 12th Five-Year-Plan period. The Plan has strategic significance in promoting shale gas exploration and development. Table 6 tells the policies of shale gas in China at present.

4.3.3. Increased investment and financing channels

In December 2011, with the approval of the state council, shale gas became the 172nd independent mineral of China. From then on, MLR would manage the shale gas resource on the basis of investment policy of independent minerals. Different from other

Table 6
Policies of shale gas in China.

Policy types	Content
Technology R&D support policy	1. Strengthen the support for technology R&D in shale gas exploration and development through the Major Projects of National Science and Technology. Shale gas exploration and development of key technologies should be classified as a priority project in the major project of "large oil and gas fields and coal bed methane development". Set up the "shale gas exploration and development demonstration project". 2. Established the National R&D (experimental) Center of Shale Gas, strengthen the center and other shale gas key laboratories constructions to establish a high-level personnel training and academic exchange base. 3. Encourage domestic enterprises and institutions to carry out joint research of key technologies of exploration and development with foreign research institutions, absorb foreign advanced and mature technologies through the introduction of foreign technology and the launch of international cooperation to form core technologies with Chinese characteristics.
Fiscal policy	
Financial subsidies	Shale gas will refer to the fiscal subsidy policies of coalbed methane. Specific policies will be issued by the Ministry of Finance.
Tax exemption	Mining right holders or applicants who obtain or apply for shale gas exploration right or mining right by laws can apply for relief fees of shale gas exploration right and mining right in accordance with the relevant provisions. For the imported equipments (including the technologies along with the equipments) which cannot be produced at home can be exempted from tariffs according to relevant provisions.
Land policy	Shale gas will receive priority of land examination and approval.
International cooperation policy	After the prospective review by MLR, then the National Development and Reform Commission reported for approval from the State Council, enterprises who engage in shale gas exploration and development can cooperate with foreign experienced corporations and introduce relevant technologies.

unconventional natural gas such as coalbed methane, having been approved to be an independent mineral, the exploration and development of shale gas will no longer be bound by the franchise of oil and gas. The mining licenses will no longer be owned by a few large monopoly enterprises. Any company who has financial strength and gas survey qualification can bid for shale gas blocks. All kinds of investment parties including foreign capitals are permitted to join this process. On May 17, 2011, MLR issued the Announcement of Intention Survey for Shale Gas Exploration Right Bidding and published the Bidding Qualifications for Shale Gas Exploration Right of 2012. There are not too many other requirements for domestic enterprises about registered capital except that the registered capital should not be less than 300 million RMB ($4.76 million) and the threshold has been greatly reduced. This broke the original monopoly regime that mining rights were only awarded to the four oil and gas companies (i.e., CNPC, Sinopec, CNOOC, Yanchang Petroleum Group) and actively encouraged other investment parties to come into the shale gas industry to promote market competition. From the experience of the United States, main exploiters and technical innovators of shale gas are thousands of small energetic private companies. The experience of the United States shows that the diversification of investors and formation of orderly competition mechanism has significant effects in the shale gas exploration and development. Deregulation has paved the way for the multiple investors into shale gas development. It is very conducive to the rapid development of shale gas exploration.

4.3.4. Plentiful foreign development experience

The accumulated experience by international shale gas industry development provides references for China. The United States who has developed shale gas for eighty years so far is the world's most successful country in shale gas development. It is also the only country that has realized shale gas commercialization [13]. The United States has drilled more than 40 thousand wells, and its output in 2009 has reached 600×10^8 m^3, accounting for 10% of the annual production of natural gas [14]. America's long-term development in shale gas provides very good reference for China.

On the one hand, the United States in the long-term exploration and development process explored a set of advanced and low-cost shale gas mining technologies, the horizontal well technology and the successful application of fracturing technology greatly improve the shale gas production. On the other hand, the United States has already formed the market mechanism of oil and gas exploration and development. Perfect development and management system has been established in the United States. Use the market mechanism to stimulate many small businesses to participate in shale gas development, then large companies expanded the scale by merging small ones. The government gave enterprises a series of preferential policies to encourage and support shale gas and other unconventional natural gas industry development. In addition, the United States has well-developed pipeline network construction. These factors are reasons for the rapid development of U.S. shale gas industry. The strong support of the national policy in the early stages of development, advanced technology systems from long period of accumulated research and the sound infrastructure system, experiences accumulated by America provide good experiences and references for the development of shale gas in China.

4.3.5. Deepened international cooperation

In order to constantly promote the shale gas industry development, the Chinese government encourages China's oil and gas companies to actively cooperate with foreign businesses with rich natural gas mining experience to learn foreign advanced technologies and management experience [15]. Chinese enterprises can propel the development of shale gas by cooperating with those transnational companies and technical service businesses who have advanced technologies and successful experiences. With the deepening of international cooperation, China's shale gas industry has obtained obvious progresses and developments that are listed in Table 7.

4.4. Threats

4.4.1. Unconfirmed resource potential

Shale gas resource potential is the basic and fundamental problems related to the prospects and industrialization of shale gas. Owing to various types of resources and strata, complex geological conditions, low degree of investigation and evaluation on the exploration combined with short-term development and inadequate investment, problems concerned resource potential of shale gas are still unsolved [16]. The relevant government agencies, petroleum enterprises and colleges from different points of view estimated that Chinese shale gas geological resource is about 30 trillion to 166 trillion cubic meters, and the technically recoverable resource is 12 trillion to 45 trillion cubic meters [17], however, the data of resource are still rough due to the low degree of exploration as well as the lack of enough practical data and key parameters such as gas volumes. For large-scale exploration and development, it is indispensable to determine the favorable target areas and regional mineable resources. Making

Table 7
Progresses of international cooperation in China shale gas industry development.

Time	Cooperation partners	Achievements	Significance
2007.10	CNPC and Newfield Exploration Company	Signed the Joint Research Agreement of Weiyuan's Shale Gas and comprehensively evaluated the development prospects of shale gas in Sichuan province	The first agreement signed for foreign cooperation in China's shale gas industrialization
2009.11	Chinese and American government	Signed the Sino-US Memorandum of Understanding (MOU) on the Cooperation of Shale Gas Development, formulated work plans for joint resource evaluation, technology cooperation and policy exchange	Upgrade the cooperation between the two countries to the national level
2010.10	CNPC and Royal Dutch Shell	Started to drill Yang 101 well, which is the first shale gas well that the two companies cooperated to exploit	Signalized that China's first cooperated projects of shale gas development Fushun shale gas in Sichuan province entering a new stage
2012.2	National Energy Administration of China and U.S. Geological Survey (USGS)	Held the 4th meeting of the Sino-U.S. workgroup of shale gas resource, discussed the eastern depression of Liaohe River's shale gas resource evaluation project	The first cooperation project between Chinese and American government in shale gas development

clear of the resource potential is a great challenge and needs plenty of investments.

4.4.2. Imperfect policy system

Although China has issued a series of preferential policies including the exemption of resource tax and mining fees to encourage the development and utilization of unconventional gas resources, the shale gas who is in its infancy of development is still short of relevant policies and effective supports to encourage the exploration and development. Many policies and institutions especially for those can promote the construction of pilot experimental zones are still under discussion. The blank of supporting policies greatly hindered the healthy and orderly development of China's shale gas. It is in urgent need of early supporting policies to facilitate the massive development of shale gas, especially the pilot development under the current market conditions and price mechanism [18].

4.4.3. Unsound management system

Shale has been confirmed to be a kind of new independent mineral in December 2011 in China. After the first round of bidding for the exploration rights had been successfully held, the second round of bidding has been held in early December 2012. However, the corresponding management system and regulatory policies including shale gas mining right bidding system, evaluation of shale gas reserves, supervision of exploration and development and so, have not been issued yet [19]. The absence of the managing system, especially the mining right bidding and regulatory systems, will limit the healthy development of shale gas exploration and development market. And it is not conducive to the industrial development and utilization of shale gas [20].

4.4.4. Deficient investment mechanism

It was not until the end of 2011 that the application of shale gas to become a new independent mineral obtained the approval of the state council. Just from then on, the MLR started to manage the specific gas according to the independent minerals investment policies. Before the approval, shale gas in China belongs to natural gas minerals. According to the Law of Mineral Resources, the exploitation of specified minerals such as petroleum, natural gas and radioactive minerals should get examination and approval from departments authorized by the State Council to obtain mining licenses. The enterprises who owned the mining rights are CNPC, Sinopec, CNOOC and CBM. Take the first round of bidding for mining rights held by the MLR in June 2011, enterprises who were invited to bid were limited to six state-owned companies includes CNPC, Sinopec, CNOOC, Yanchang Petroleum, CBM and Henan Provincial Coal Seam Gas Development and Utilization co. Private enterprises were not among the invited. This was almost the repeat of coalbed methane. It is reported that the reason why coalbed methane developed in China slowly in the past 15 years was that the mineral rights were held tightly by large petroleum enterprise [21]. These large enterprises used the mining rights to get land enclosure but without starting any relevant exploration and development. If shale gas investment shall not be diversified, it will only retrace the approach of coalbed methane, and hence the possibility of development is very small.

4.4.5. Poor infrastructure

At present China's network density is extremely low, and the total length of pipeline is only about 100 thousand kilometers, by contrast, the United States whose area is slightly smaller than China but has nearly 2 million kilometers of natural gas pipeline yet [22]. The lagging of related infrastructures including gas pipeline network, gas storage warehouse seriously restrict the unconventional gas exploitation and utilization and the industrial development. On the one hand, zones full of unconventional gas are relatively remote and far away from the major market. Considering the poor traffic condition, unsound and incomplete infrastructure, China's development of unconventional gas will face the problems concerned no network, no market and no road. On the other hand, for places near pipeline network with good transportation conditions, the produced unconventional gas cannot be put into the network because there is not a fair and open access mechanism that can reach target markets economically and effectively. It hence significantly increases the intermediate costs, and finally restricts the development and utilization of shale gas [23].

According to the above SWOT analysis of the strengths, weaknesses, opportunities and threats on the development of the shale gas industry in China, we can draw the distribution of factors which affect the development of Chinese shale gas industry as shown in Fig. 4.

5. Development strategies of China's shale gas industry

5.1. SWOT strategic matrix of China's shale gas industry

Through the above systematic analysis about strengths, weaknesses, opportunities and threats of China's shale gas industry, we come to the SWOT strategic matrix of Chinese shale gas, including the strength–opportunity (SO) strategy, weakness–opportunity (WO) strategy, strength–threat (ST) strategy and weakness–threat (WT) strategy. SO represents the strategy that plays industry internal strengths and takes advantage of external opportunities. WO strategy represents the strategy that uses external opportunities to compensate for internal disadvantages. ST represents the strategy that utilizes internal strengths to avoid or reduce the

external threats. WT represents the strategy that circumvent external threats while to make up for internal disadvantage. The contents of the strategy are displayed in Table 8 below.

5.2. SWOT strategy formulation of China's shale gas industry

Based on the above analysis process, we clearly analyze four strategies as well as their specific contents. In each of the strategic context, various factors of the strengths, weaknesses, opportunities, threats are sorted according to priorities. Therefore, the specific strategies under the same strategy have different priorities. The following is a detailed analysis of the strategies and corresponding contents.

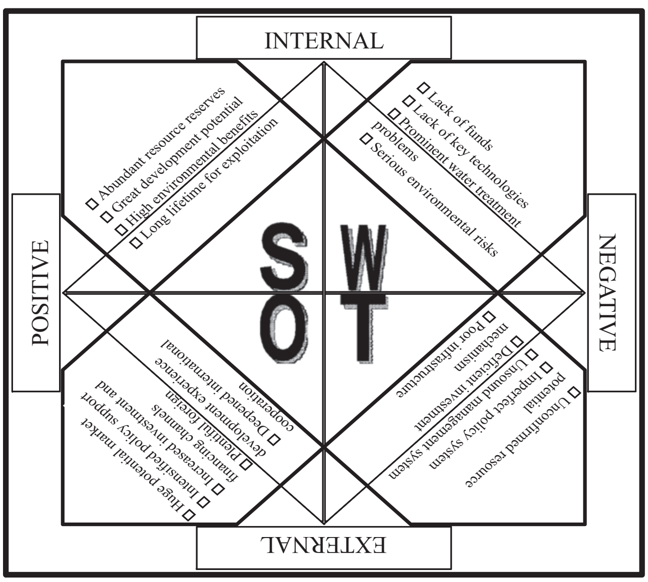


Fig. 4. Factors distribution map which affect the development of China's shale gas industry.

(1) SO strategy:
First, take the opportunity of the great demand in energy and closely center on the advantage of production scale, make full use of the rich resources reserves of China's shale gas to accelerate the exploration and development speed [24] (S1, S2, S4, O1);
Second, seize the strategic opportunity that government greatly supports in accordance with all kinds of development planning made by the authority to promote China's shale gas industry development [25] (S1, S2, O2, O3);
Third, on the basis of broad market prospects and resource potential, attract foreign companies to cooperate on shale gas projects [26], actively learn from international shale gas industry development experience (S1, S2, O4, O5).

(2) WO strategy:
First, Government should strengthen the investment and support for shale gas exploration development [27], attract investment funds from multi channels, and at the same time, encourage to carry out international cooperation and attract international capital to come into China's shale gas industry (W1, O2, O5);
Second, implement the strategy of personnel training, strengthen the development of key scientific and technological problems and promote the theoretical innovation of resource exploration to break the bottlenecks of shale gas mining technology [28] (W2, O2);
Third, positively introduce and absorb international shale gas development advanced technologies, combine introduction and innovation to master the key technologies of shale gas development (W2, O5);
Fourth, conform to the trend of rising demand in clean energy [29], intensify the shale gas development efforts and pay attention to environmental protection, strengthen environmental impact assessment of shale gas exploration and development, especially the potential groundwater pollution caused by the use of hydraulic fracturing (W3, W4, O1).

(3) ST strategy:
First, strengthen the shale gas geological survey and research, clearly define China's shale gas resource reserves and verify mining resources potential (S1, T1);

Table 8
SWOT strategic matrix of China's shale gas industry.

Internal	**External**	
	S (strengths)	**W (weaknesses)**
O (**opportunities**)	**SO Strategy** **P1** Make full use of the gas reservoir to speed up the development process and meet the energy demand of the economic development (S1, S2, S4, O1) **P2** Seize the opportunity that government supports the development of the shale gas industry and actively invest in shale gas and related industries (S1, S2, O2, O3) **P3** Attract foreign projects, carry out international cooperation, and learn from international experiences (S1, S2, O4, O5)	**WO Strategy** **P1** The government should increase funding and supports, attract funds through multiple channels, carries out international cooperation, and attracts international capital (W1, O2, O5) **P2** Focus on personnel training, strengthen the scientific and technological research, and promote resource exploration and theoretical innovation (W2, O2) **P3** Introduce and absorb advanced international technologies, combine with the introduction and innovation, and master key technologies (W2, O5) **P4** Assess the impact of development on the environment and pay attention to environmental protection (W3, W4, O1)
T (**threats**)	**ST Strategy** **P1** Make clear about resource reserves and prove mining potential (S1, T1) **P2** Develop a comprehensive strategic planning, intensify policy support and introduce preferential policies (S1, S2, T2) **P3** Specify resources management system, maintain the order of mining rights and learn from foreign experience (S1, S2, T3) **P4** Create an open and competitive market, break the monopoly, and form large-scale investment mechanism with diversified participants (S1, S2, T4) P5 Promote related infrastructure construction, and strengthen the construction of pipeline network (S1, S2, T5)	**WT Strategy** **P1** Strengthen governmental support, introduce preferential policies, attract multi-investment subjects, form large-scale, diversified investment mechanism and use policy efforts to resolve the key issues faced by the shale gas (W1, T2, T4) **P2** Encourage independent research and development and master the key technologies (W2, T1)

Second, further strengthen the policy research of shale gas, formulate more complete strategic planning [30]; increase the supporting efforts, introduce more favorable policies that are conducive for the development of shale gas (S1, S2, T2);
Third, standardize the resource management system [31], research and form the resource management and regulatory measures which are adapted to shale gas, maintain the order of the mining rights, and learn from foreign experience to form a new mode for China's shale gas in order to lay the foundation for shale gas to play its reserves advantage. (S1, S2, T3);
Fourth, strengthen the shale gas exploration and development management, create open competition environment [32], promote the diversification of investors, encourage small and medium-sized companies or private capitals who are able to participate in the exploitation of shale gas with solid strength to break the monopolistic situation in exploration and development of oil and gas resources at home and abroad [33], and form the large-scale and diversified mechanism (S1, S2, T4);
Fifth, promote shale gas infrastructure development, especially the network construction [34], and gradually build nationwide shale gas backbone network and local network that can meet the need of the local areas (S1, S2, T5).

(4) WT strategy:
First, more efforts should be put into the supporting of shale gas industry [35], issue more kinds of favorable policies to attract investment parties from all walks of society to enter into the shale gas industry to form an investment mechanism that is large-scaled and diversification [36]; use the power of policies made by the authority to solve the problems exist in the early stage of shale gas industrialization (W1, T2, T4);
Second, encourage domestic businesses to research and develop the technologies that are useful in shale gas development [37], master the key technologies to support the further development of shale gas (W2, T1).

6. Conclusions

With the rich resource and wide distribution, China's shale gas industry has a bright future for exploitation. The Chinese government encourages the development and utilization of shale gas and positively promotes the industrialization of shale gas. The supporting efforts are increasingly greater and greater. However, as it is still in the initial stage of development, there are many weaknesses and threats internally or externally in shale gas development. Low level of industrialization, absence of supportive policies, lack of advanced technologies, sufficient funds and professional talents for resource management, altogether limit extensive development of China's shale gas. Therefore, Chinese government has started to formulate preferential and supportive policies to guide and support shale gas industrialization development while encourage and promote international cooperation. Based on the combination of SWOT matrix analysis, this paper concluded series of strategies for shale gas development: strength–opportunity (SO) strategy, weakness–opportunity (WO) strategy, strength–threat (ST) strategy and weakness–threat (WT) strategy. Then we propose the specific content of corresponding strategies including increasing the efforts for resource potential exploration, consummating government support policies, attracting the investors from all walks of society to join the industry, adhering to independent innovation meanwhile introducing the key technology, carrying out international cooperation in shale gas development and strengthening the pipe network infrastructure construction. Future research can focus on the government control policy, the key technologies of shale gas development, formulating industry standards, the influence on Shale gas industry as well as the pattern of China's energy, the external shale gas development and so on. Thereby it can provide theoretical support for the rapid and healthy development of the shale gas industry in China.

With the promulgation of the Shale Gas Development Plan (2011–2015), Chinese government has set out to develop the shale gas. The plan (2011–2015) of the shale gas defines the 12th five-year-plan period as a laying foundation period, and the major task of China during this period is to do well in the start of shale gas exploration and development, and in the 13th five-year plan period it will become a trend of rapid development.

Acknowledgement

This paper is supported by National Natural Science Foundation of China (Granted No. 71273088) and Humanities and Social Foundation by the Ministry of Education of China (Granted No.11YJA790218).

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